Understanding the Non-development Processes of Ex-Gaston (2010)

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A collaborative study of the PREDICT field campaign

Introduction (Tropical Storm Gaston 2010)

- Developed from a African Easterly Wave on September 1, 2010.
- Quickly weakened to a remnant low despite warm SSTs.
- Never re-intensified.
- Gaston was profiled extensively during PREDICT

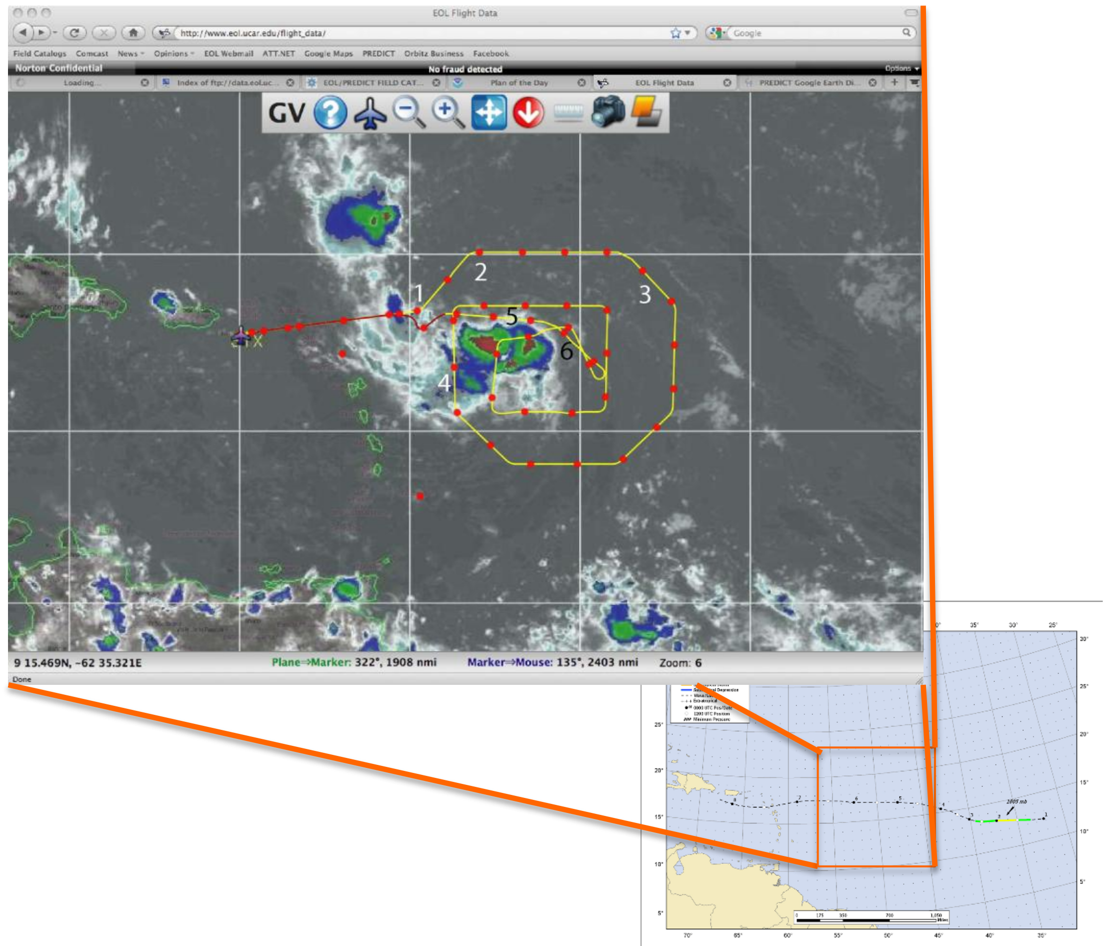


Figure 1. Best track positions for Tropical Storm Gaston, 1-2 September 2010.

National Hurricane Center (2010)

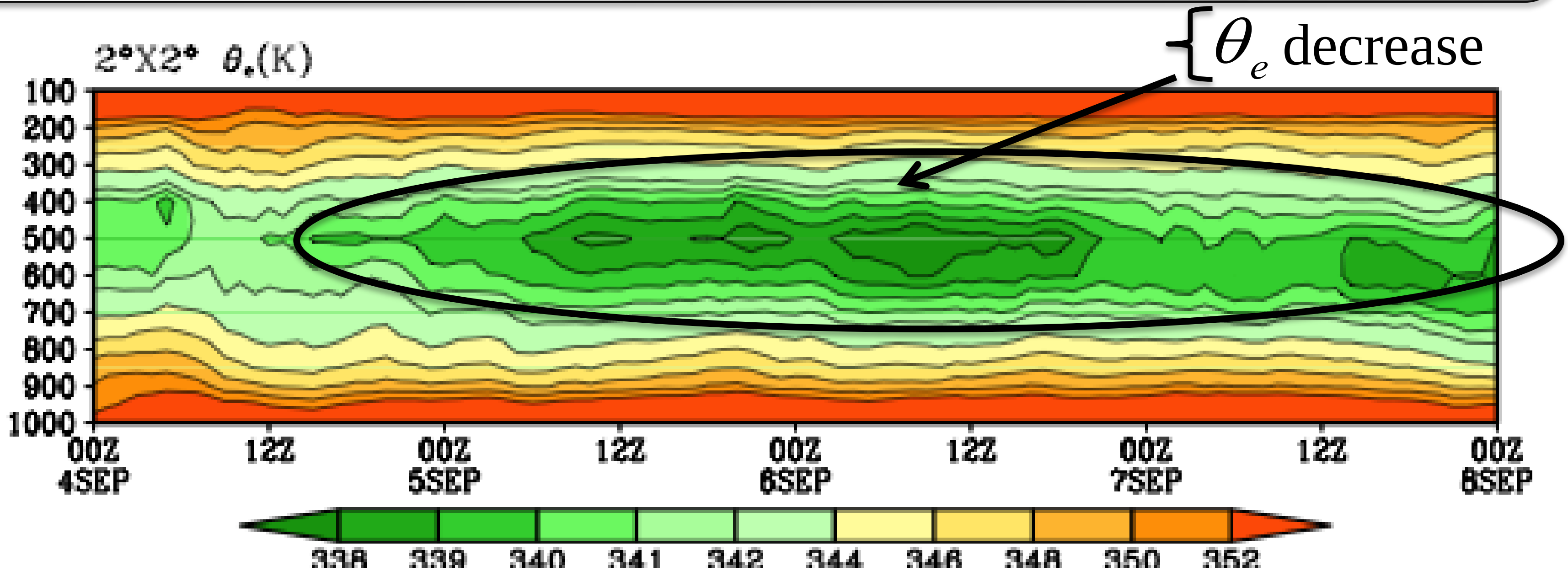
Objective

- The major question being asked…
  - What inhibits the re-intensification process of Gaston (2010)?
- How does the evolution of Gaston (2010) compare to Tropical Storm Fay (2008)?
  - Developer vs. Non-developer?

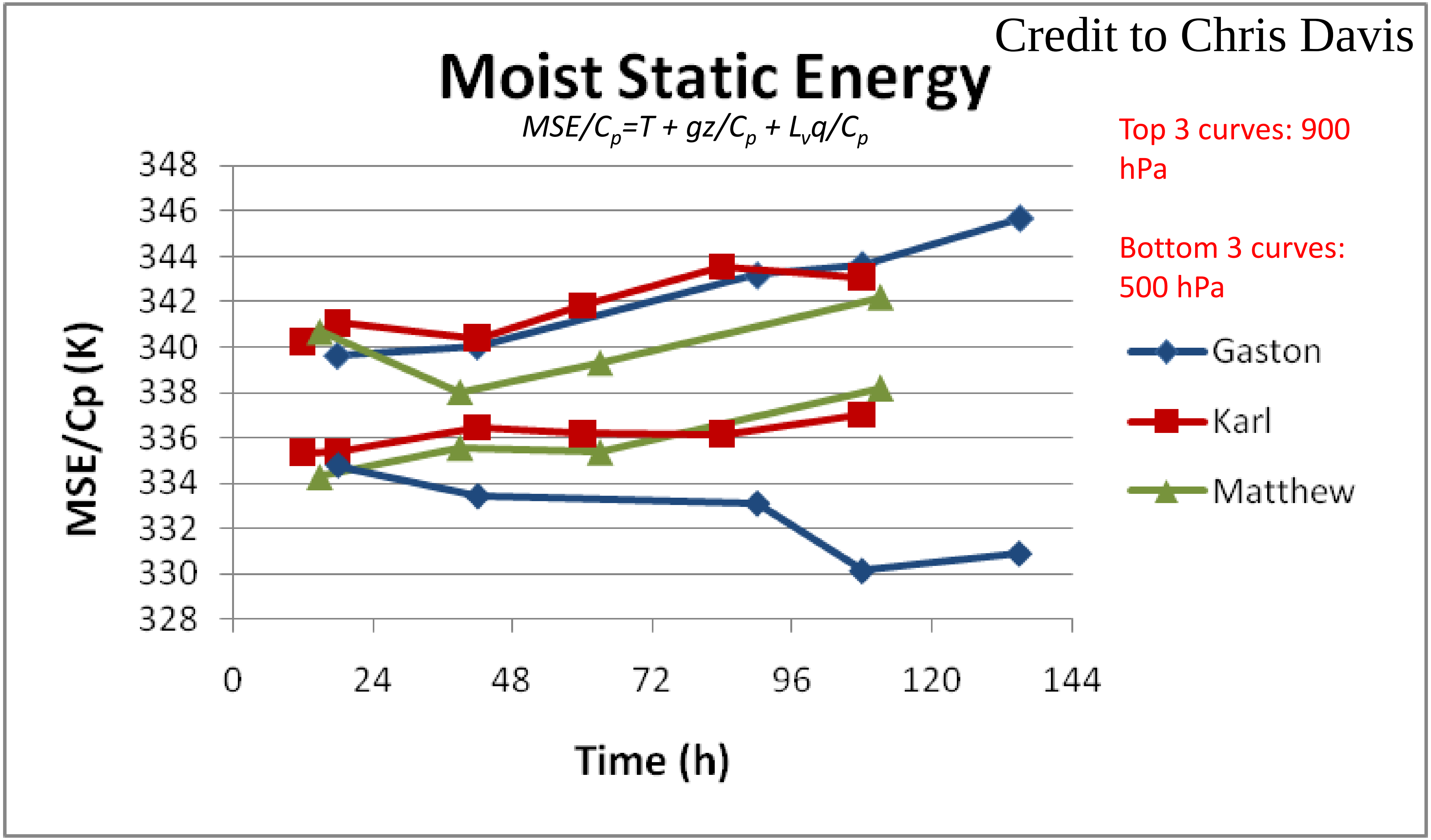
Model Setup

- Advanced Research Core of Weather Research and Forecasting model (WRF-ARW) v3.2.1.
- Three grid nested domain
  - Spatial domain – 27, 9, and 3 km.
- Initialized and driven by ERA-Interim 6-hourly data; Runtime – 00Z04SEP2010 – 00Z08SEP2010
- Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT)

Mid-level Drying

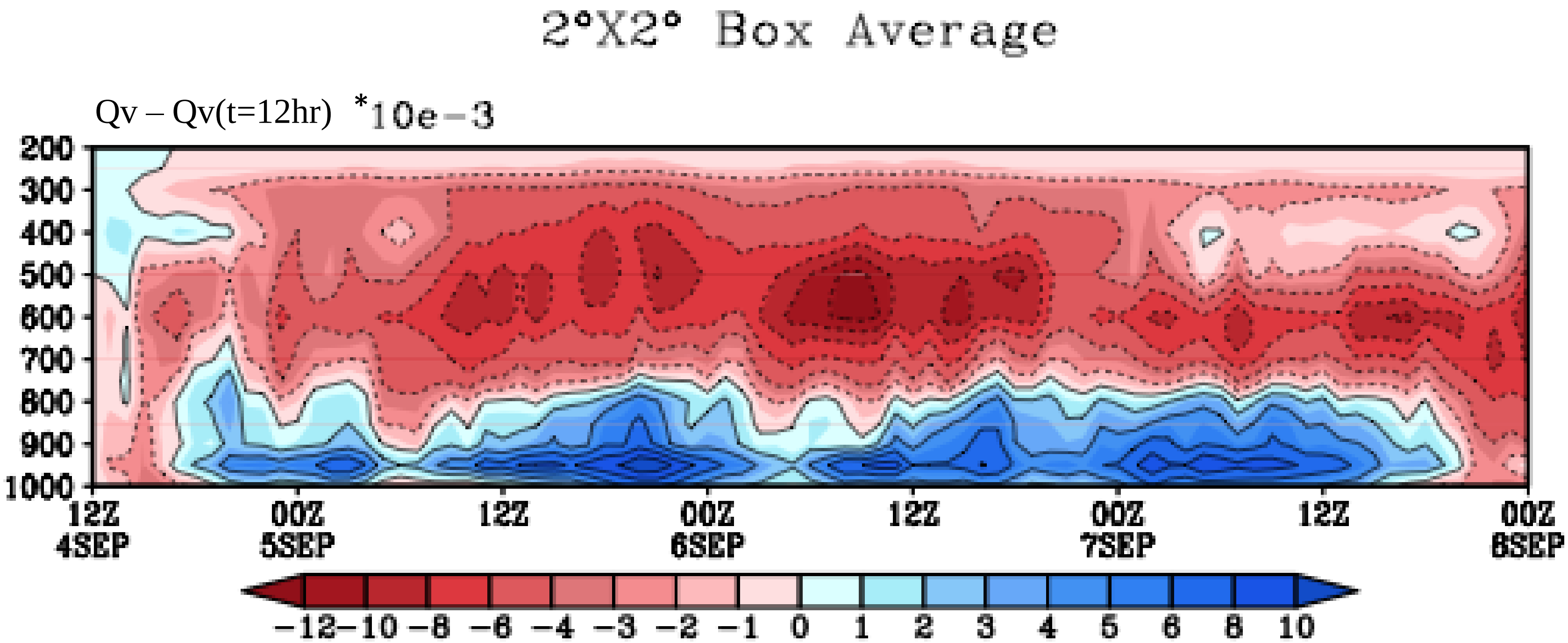


- Shows a reduction of θ_e in the middle troposphere. This reduction indicates the occurrence of middle tropospheric drying.
- Why the drying?



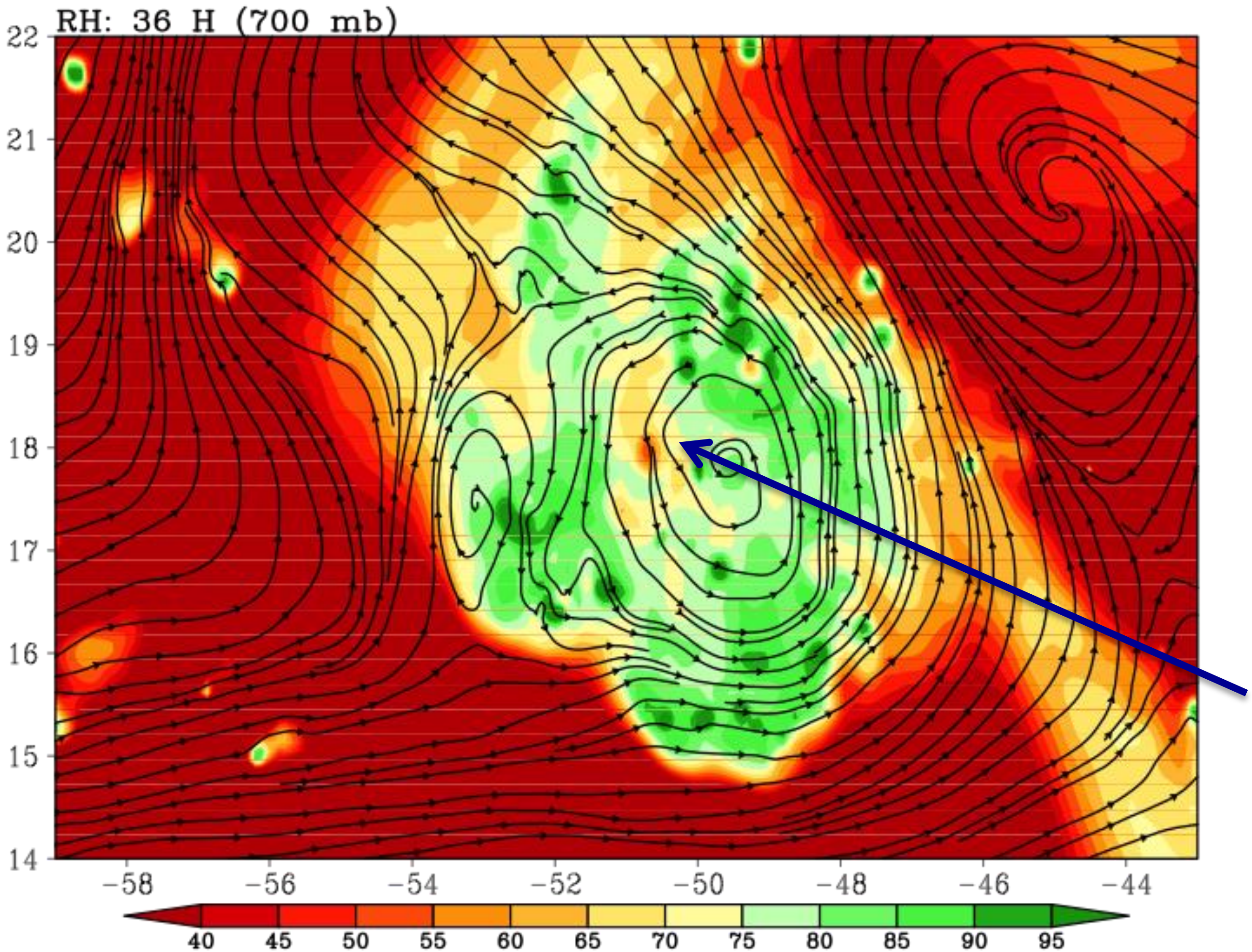
Shows gradual decrease in MSE in the middle troposphere which is consistent with our model results.

Time height cross section of mixing ratio difference



Shows a decrease in water vapor mixing ratio in the middle troposphere (between 1-2 g/kg change).

700 mb RH and Storm Relative Streamlines



Cp = -6.3 ms^{-1}
t = 36 hours

Pockets of dry air in vicinity of center of circulation
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Assessment of the RH field reveals pockets of dry air near the center of circulation

Possible Causes of Mid-level Drying

1. Mid-level inflow associated with the transverse circulation.
2. Entrainment due to the pouch-relative flow.
3. Lateral entrainment due to transient eddies.
4. Downward transport of dry air from the upper troposphere.

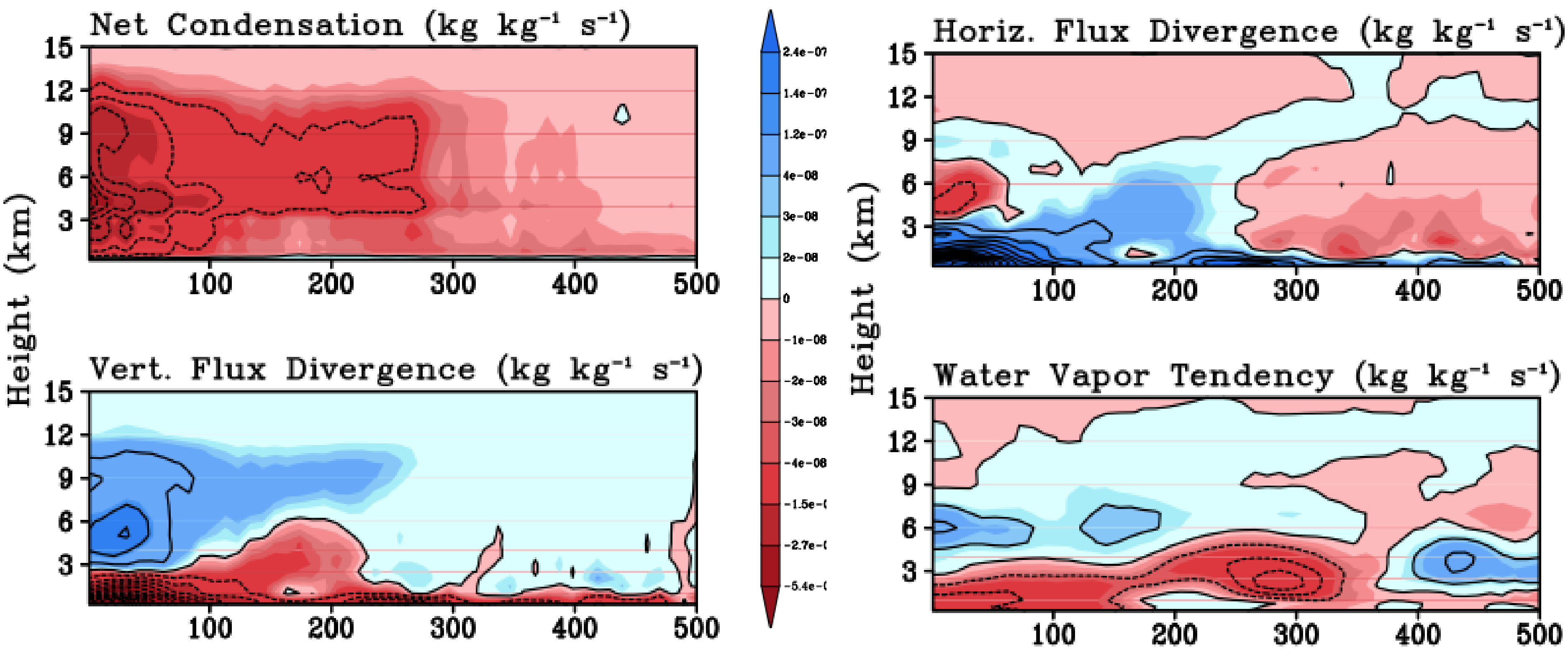
- Therefore, we must analyze each possible cause.

Moisture Budget (Budget Terms)

$$\frac{\partial q_v}{\partial t} = -\nabla \bullet (q_v V') - \frac{\partial (q_v w)}{\partial z} + q_v \left(\nabla \bullet V' + \frac{\partial w}{\partial z} \right) + NC + B_v + D_v$$

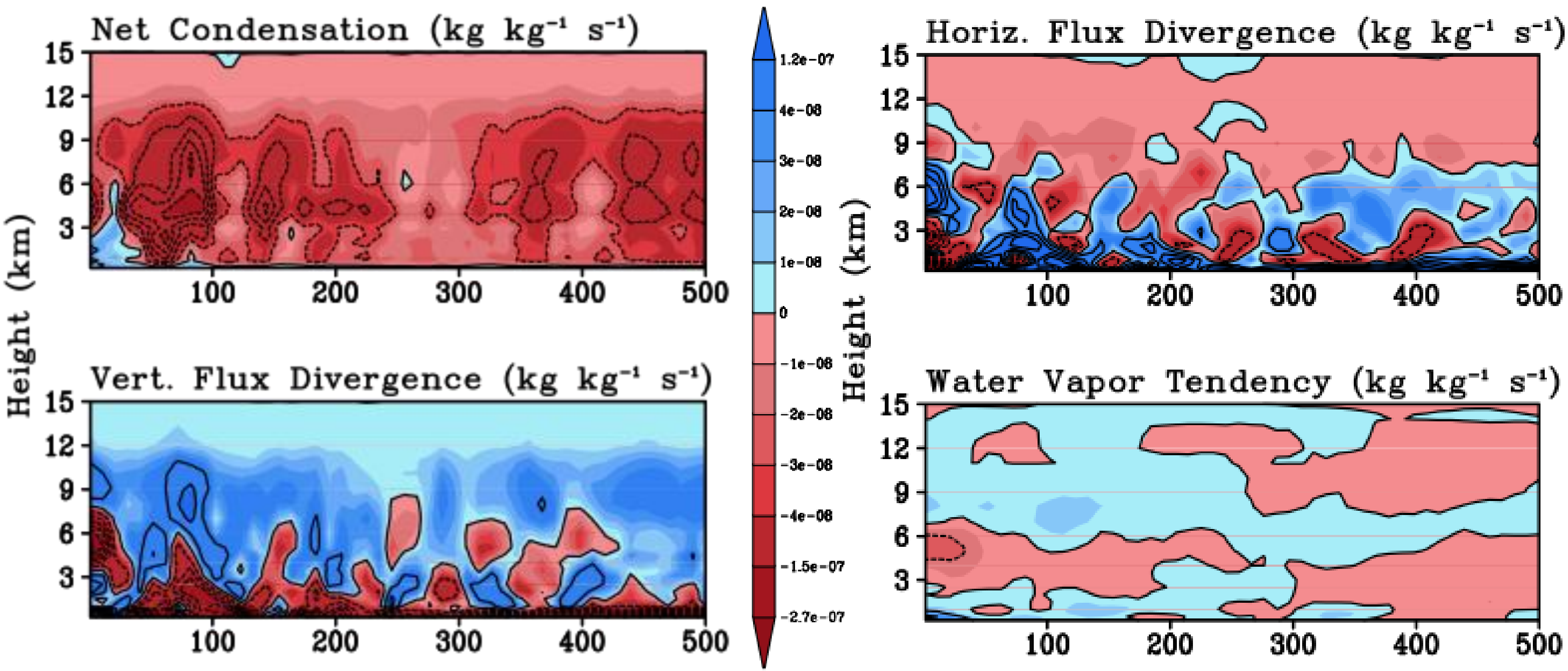
- Adopted from Braun (2006)
- Net condensation term outputted directly from WRF-ARW.
- Coupled Qv tendency due to PBL parameterization
- Diffusion term negligible.

A Developer: Tropical Storm Fay (2008) Water Budget (Temporal Average: 36-60 hr (wave stage))

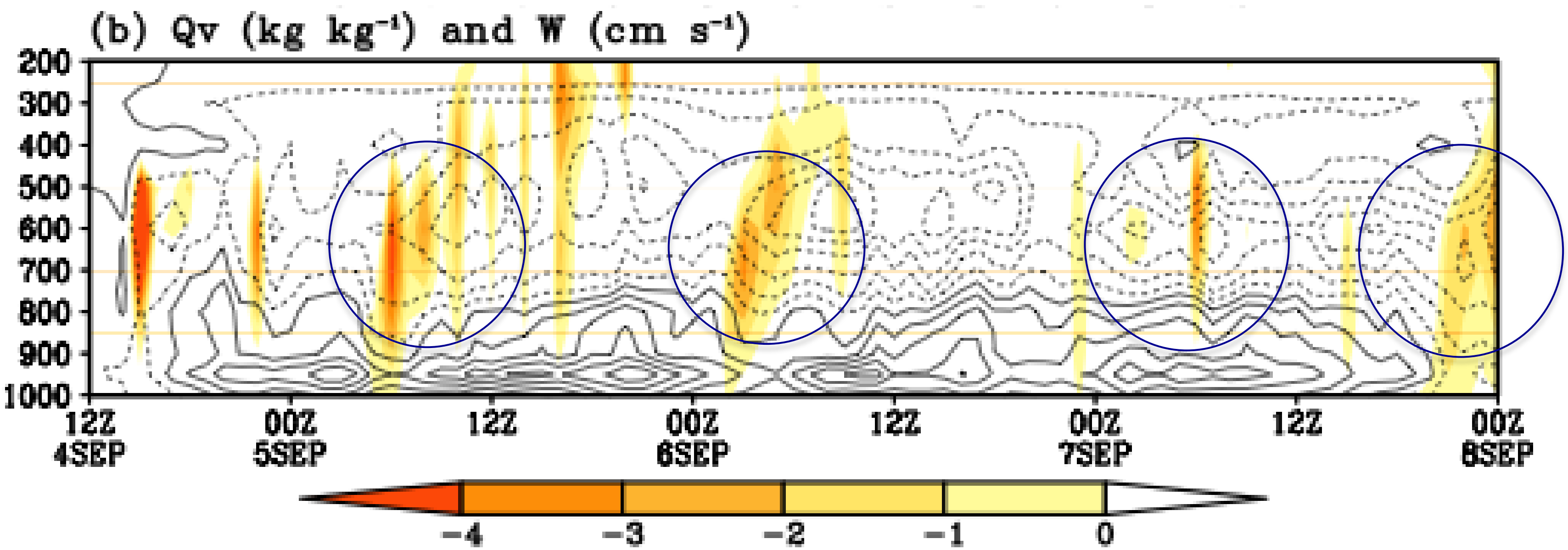


Budget Analysis (Ex-Gaston 2010)

36 – 60 Temporal Average

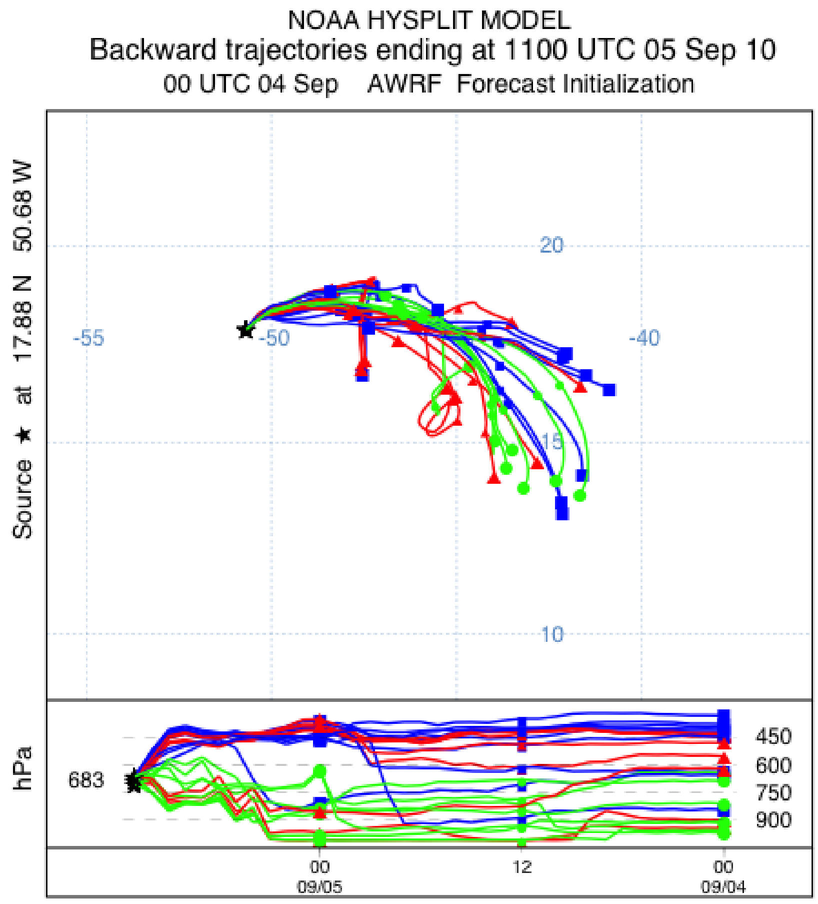


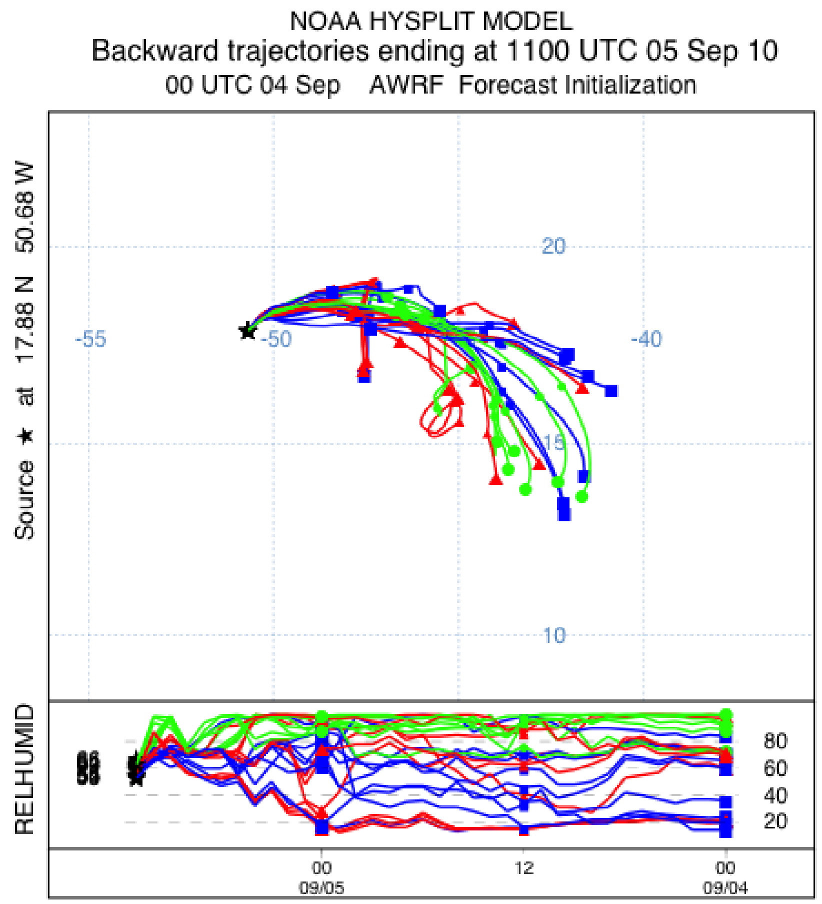
Time Series of Qv and W



Shows a time height cross-section of mixing ratio change (contour) and vertical velocity (shaded). Note the indication of downdrafts are accompanied by a reduction in mid-level mixing ratio.

3-D Trajectory Analysis (ensemble run)

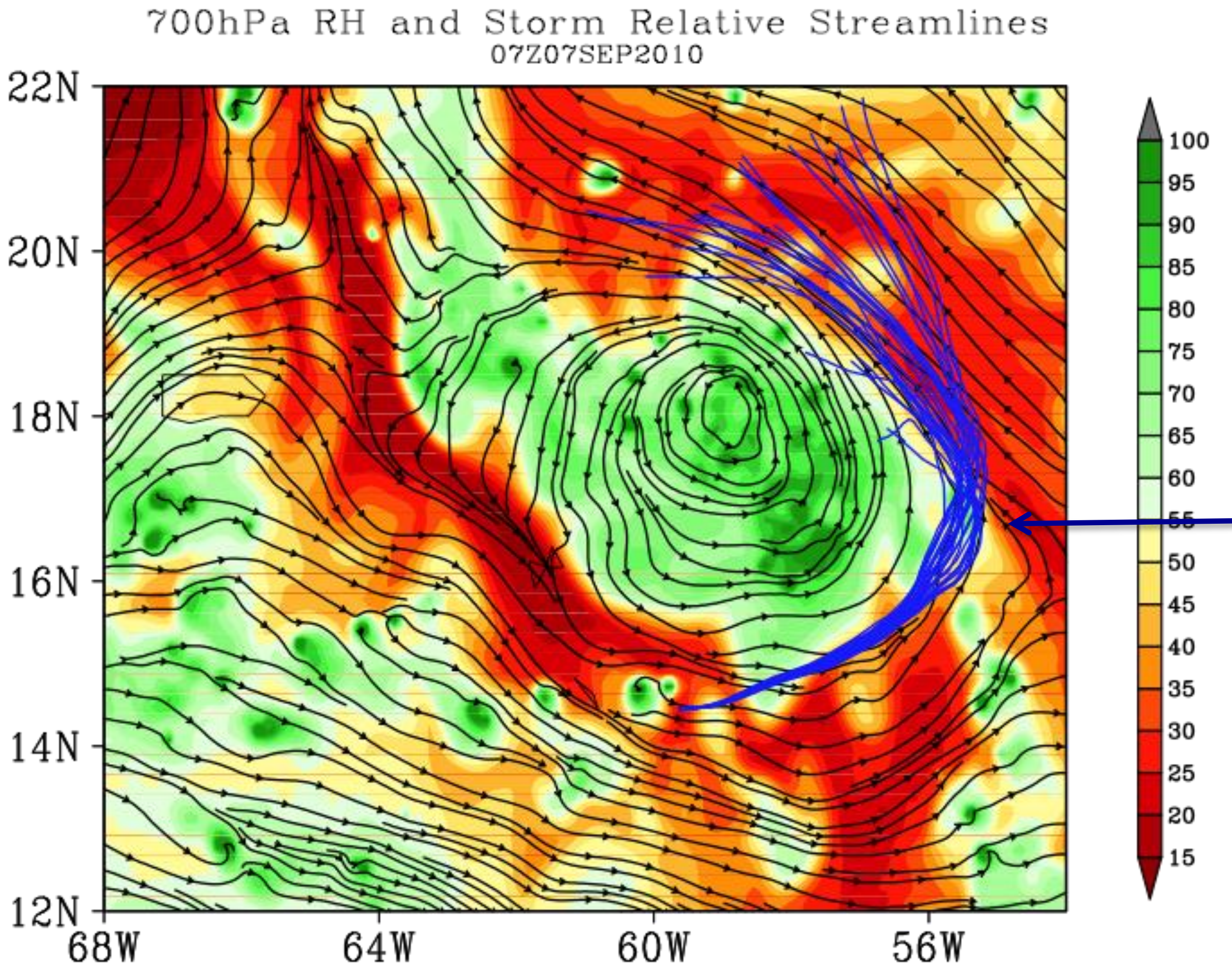




- Some evidence shows the source of drier air is from the upper troposphere. This suggests the possibility that dry air is vertically transported, thus the potential for the modification of the mid-level environment.

3-D Trajectory Analysis (ensemble run)

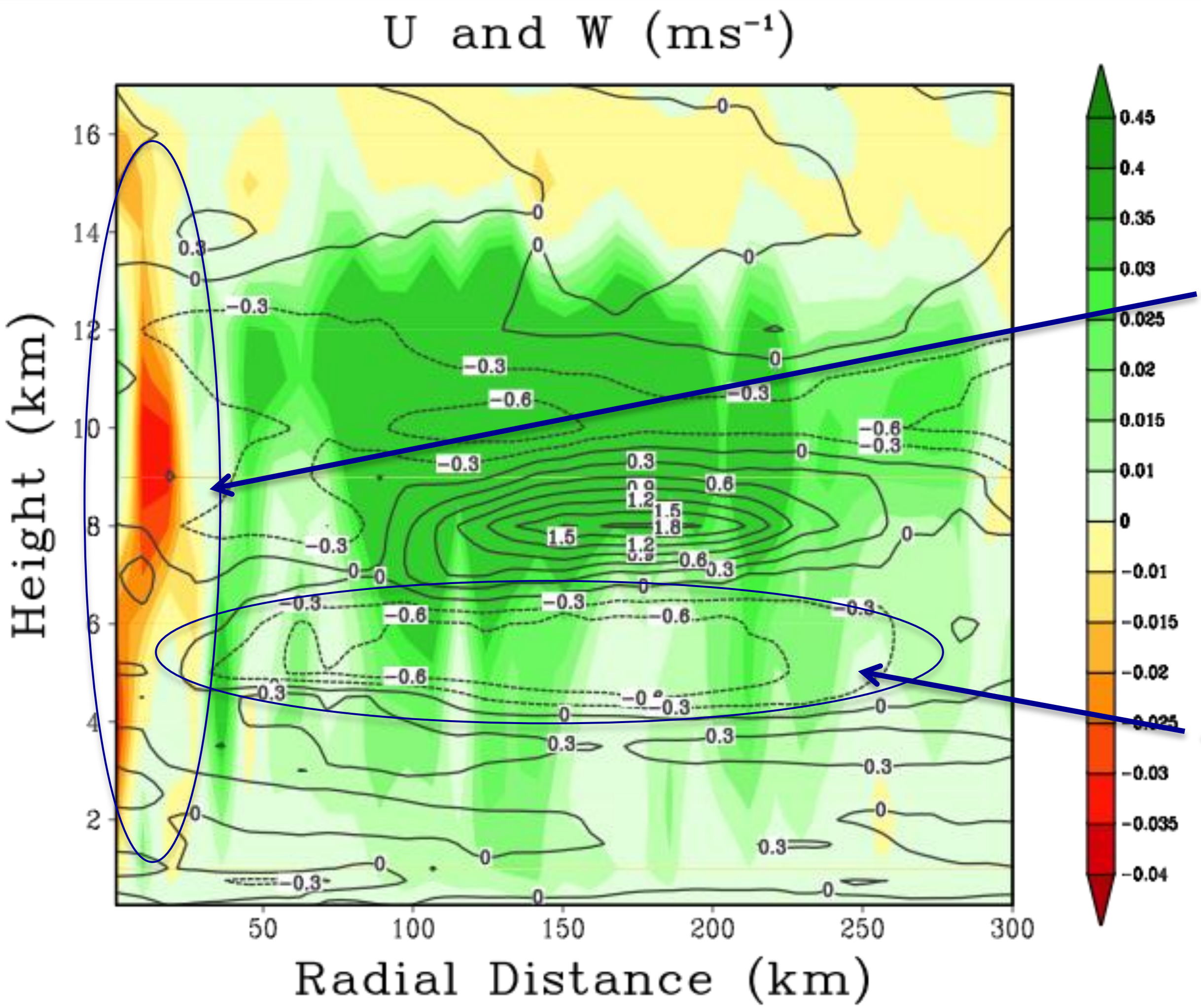
Storm Relative Ensemble Trajectories



Particle trajectories follow closely to storm relative streamlines.

Particle trajectories not shown to impact center of circulation.

Secondary Circulation (Gaston)



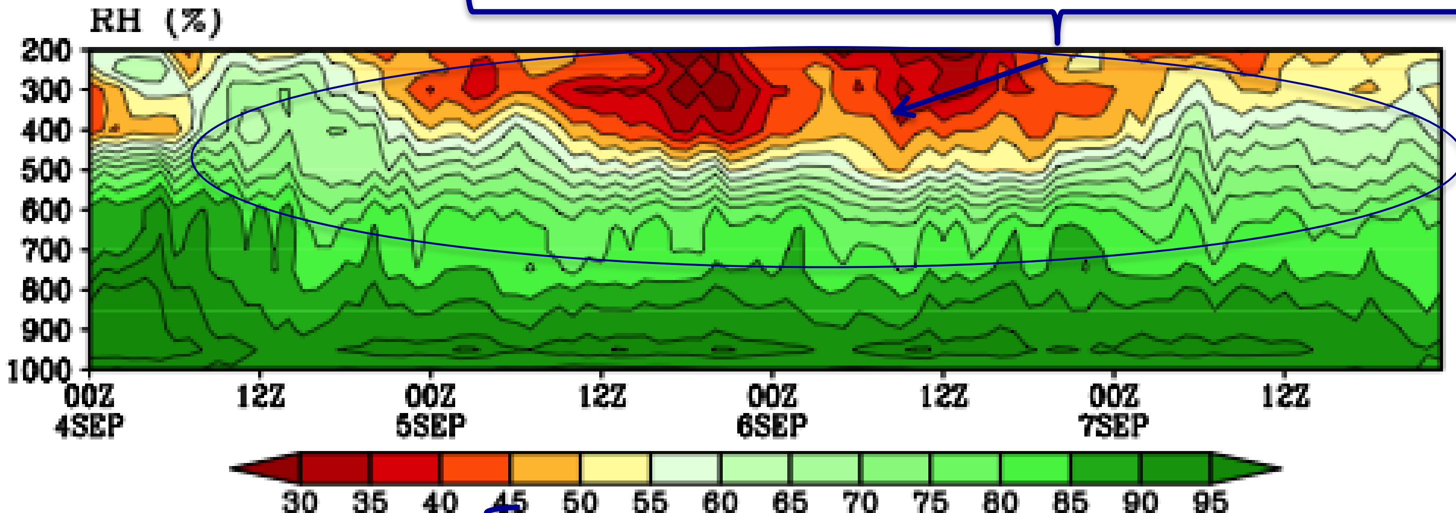
Negative vertical velocities within 25 km of the center of circulation.

Weak radial inflow in low and middle troposphere.

RH: Fay (2008) vs. Gaston (2010)

Gaston (2010)

Persistent drying in the middle and upper troposphere

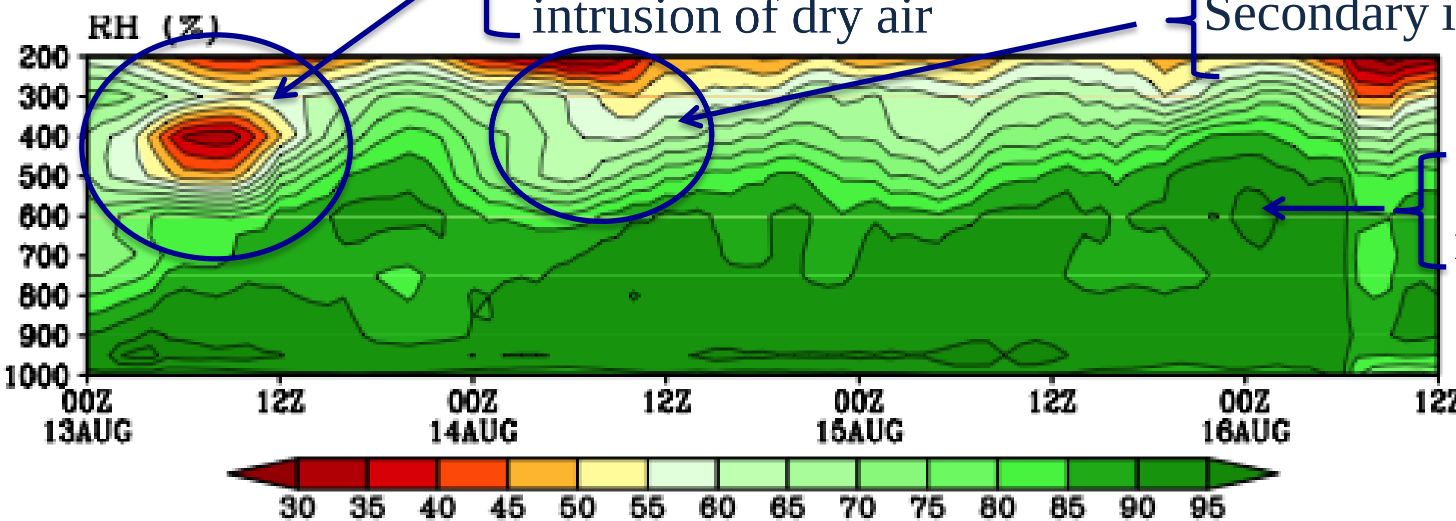


Fay (2008)

Upper-tropospheric intrusion of dry air

Secondary intrusion of dry air

Deep layer moistening



Summary

- The non-development of ex-Gaston is likely due to drying in the middle troposphere (400-700mb), which leads to reduction in equivalent potential temperature.
- Moisture distribution and trajectory analysis suggest that the mid-level drying is mainly due to the vertical transport of drier air from the upper troposphere, which induces dry air very near the center of circulation.
- The transverse circulation shows a weak mid-level inflow—it takes 2-3 days for dry air to move near the pouch center from the periphery (i.e. the circulation center is generally well protected from **lateral** dry air intrusion at the middle troposphere)